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SOME QUALITATIVE ASPECTS OF BITONAL COMPLEXES¹

By CARROLL C. PRATT

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The present investigation neither pretends to a resolution of the problem of fusion in its systematic context nor to a new determination of the order of degrees of fusion. It was initiated under the conviction that there were within reach a point of view and a method, which would single out for separate examination certain phenomenological characteristics which enter into the total impression set up by two tones when presented simultaneously to the organ of hearing. The literature on tonal fusions, although rich in experimental studies undertaken from various angles of approach, is nevertheless far from being in a settled state. The suspicion is hard to escape that much confusion has resulted from a failure to take into consideration the fact that any judgment upon the nature of fusion is inevitably ambiguous unless directed upon one univocal characteristic of the tonal impression.

A review of the literature would be unnecessary iteration in the present article.² Many of the controversies to which Stumpf's classic volumes gave rise are due to Stumpf's ambiguity of definition and procedure, or at best, to a misunderstanding on the part of others of his exact concept of fusion. It is not surprising that misunderstandings should arise. As a rule Stumpf displays a predilection for calling fusion "dasjenige Verhältnis zweier Inhalte, speciell Empfindungsinhalte, wonach sie nicht eine blosse Summe sondern ein Ganzes bilden."³ Nevertheless by way of amplification, Stumpf refers to fusion as "dasjenige Verhältnis zweier Empfindungen, in folge dessen" the total impression of the more perfect fusions "immer mehr dem Einer Empfindung nähert und immer schwerer analysirt wird."⁴ Of

¹ From the Psychological Laboratory of Clark University.

² For a recent review of the literature, see W. Kemp, Methodisches und Experimentelles zur Lehre von der Tonverschmelzung, *Arch. f. d. ges. Psychol.*, 1913, 29, 139-181.

³ C. Stumpf, *Tonpsychologie*, 1890, ii, 128.

⁴ *Loc. cit.*

course such aspects of fusion are secondary, but Stumpf uses them in his experiments as criteria for fusion. Again Stumpf calls fusion "eine unveränderliche Eigentümlichkeit des Empfindungsmateriales, welche immer noch übrig bleibt, wenn alle anderen Hindernisse der Analyse beseitigt werden, und welche gerade nachdem die Analyse vollzogen und die Töne deutlich als zwei erkannt sind, ebenfalls erst in sich selbst bemerkt werden kann."⁵ "Wie sich dies ausnimmt, muss man eben hören und kann es Niemand klarmachen, der nicht hören oder Gehörserscheinungen nicht beobachten kann."⁶ Stumpf throws in another confusing implication when he remarks that "der Zusammenklang zweier Töne nähert sich bald mehr, bald weniger dem Eindruck Eines Tones, und es zeigt sich, dass dies um so mehr der Fall ist, je konsonanter das Intervall ist."⁷ Wundt⁸ has brought the reproach against Stumpf of creating a purely logical concept of fusion, in spite of Stumpf's manifest efforts to base his inductions on phenomenological experience. Others,⁹ accepting the Stumpfian doctrine on its theoretical side, or, on the contrary, dispensing with it, or at times modifying it, have centered their interest in the search by repeated experiment and observation for a more stable order of degrees of fusion. Still others¹⁰ doubt the justification for introducing a unique notion like fusion into the psychological system and attempt to account for the phenomenon in terms of analysability, unitariness, harmony or what not, or else to work out an entirely new definition of fusion.

Kemp's experiments are an attempt to separate out the factors which may enter into the phenomenon of consonance. The results indicate the operation of the following four *Merkmale*: fusion in the sense of that "unveränderliche Eigentümlichkeit welche immer noch übrig bleibt, wenn alle anderen Hindernisse der Analyse beseitigt werden;" pleasantness and unpleasantness; *sinnlicher Wohlklang*; *sinnliches Zusammenpassen*, a sort of relationship by virtue of which the components of an interval seem to belong or go together; and *harmonisches Zusammenpassen*, the need of resolution (*Auflösungsbedürfniss*).¹¹ Unfortunately, however, Kemp gives no clue as to the structural na-

⁵ *Ibid.*, 127f.

⁶ *Konsonanz und Dissonanz*, 1898 44.

⁷ *Ibid.*, 35.

⁸ *Physiologische Psychologie*, 1910, 6 Aufl., ii, 124ff.

⁹ E.g., O. Külpe, *Grundriss der Psychologie*, 1893, 289ff.; A. Faist, Versuche über Tonverschmelzung, *Zeits. f. Psychol.*, 1897, 15, 102ff.; Th. Lipps, *Leitfaden der Psychologie*, 1909, 3 Aufl., 98ff.; Tonverwandtschaft und Tonverschmelzung, *Zeits. f. Psychol.*, 1898, 19, 1ff.; W. Kemp, *op. cit.*, 153; T. H. Pear, The experimental examination of some differences between the major and minor chords, *Brit. J. Psychol.*, 1911, 4, 56ff.

¹⁰ Wundt, *Phys. Psychol.*, 1910, ii, 121; F. Krueger, Beobachtungen an Zweiklängen, *Philos. Stud.*, 1900, 16, 307ff; Die Theorie der Konsonanz, *Psychol. Stud.*, 1906, 1, 305ff; 1907, 2, 205ff; 1909, 4, 201ff; 1910, 5, 294ff; P. Natorp, *Göttinger Gel. Anz.*, 1886, 145ff; 1891, 789ff; H. Cornelius, Ueber Verschmelzung und Analyse, *Vierteljahrsschr. f. wiss. Philos.*, 1892, 16, 404ff; E. Buch, Ueber die Verschmelzung von Empfindungen, besonders bei Klangeindrücken, *Philos. Stud.*, 1899, 15, 1ff, 183ff.

¹¹ Kemp, *op. cit.*, 181-203.

ture of these *Merkmale*: an omission regrettably common in work on the psychology of fusion.

The present experimental investigation was begun in the fall of 1919 and continued until the spring of 1921 in the Psychological Laboratory of Clark University.

PRELIMINARY SERIES

The *O*'s who took part in the experiment were G, Dr. E. G. Boring, who worked with knowledge of the problem; F, Dr. S. W. Fernberger; L, Dr. L. D. Boring; Y, Dr. M. Yokoyama; and B, Miss M. Bates. All were highly trained in observation. B was the most "musical" *O*, but found no difficulty in abstracting from musical knowledge. L had absolute recognition of single pitches but had no musical recognition of intervals. Y had but slight "ear" for occidental music and could not recognize intervals musically at all. G and F had no musical recognition of intervals.

Three Stern variators (210-400, 310-600, and 410-800 d.v.) were used as stimuli throughout the experiments. They were placed side by side on a wooden support 80 cm. from the floor on one side of the experimenting room. *O* sat with his back toward the source of sound at a distance of 1.5 m.

Preliminary experiments were conducted to determine roughly the rank order of degrees of fusion for the five *O*'s on the basis of rapidity of analysis, a method suggested by Külpe.¹² A Bergström chronoscope, placed alongside the variators and connected with the reaction key on the arm of *O*'s chair, was used to measure reaction times. The octave, fifth, fourth, sixths, thirds, tritone, sevenths, and seconds were used. The order of presentation was varied from time to time, and occasional *Vexirversuche* of single tones were thrown in. Fifty reactions upon each interval were taken.

The following typewritten instructions were read by *O* at the beginning of each session: "Following the 'ready' signal, you will be presented with (a) single notes, and (b) two-note complexes. The duration of the stimulus will be 0.5 sec. You are requested in each case to react upon the key as soon as you have decided whether the sound which you hear is that of one note or two notes, stating afterwards whether the judgment was 'one,' 'two,' or 'doubtful.' In case of the latter, indicate, if possible, the direction in which the judgment inclined."

Proceeding on the uncritical assumption that degrees of fusion are inversely proportional to rapidity of analysis, a scale of degrees of fusion was calculated from the reaction times of each *O*. The rank orders thus obtained were utilized in the next step of the preliminary experiments.

The purpose in this second part of the preliminary experiments was to present tonal complexes to *O* which could not readily be analyzed into separate components and to secure from *O* qualitative descriptions of the impressions thus set up. Although Stumpf¹³ insists that the phenomenon of fusion still persists after analysis is complete, it was deemed worth while to forestall analysis at least in part by combining the intervals which had yielded less quickly to analysis in the preceding experiments into triads that could be but very imperfectly separated. (E.g., the first six intervals which resulted from the foregoing experiments for L were in order of difficulty of analysis: octave,

¹² *Grundriss der Psychologie*, 1893, 239.

¹³ *Tonpsychologie*, ii, 127f.

fifth, fourth, major third, minor sixth, major sixth. These intervals were combined into the following triads: d-g^b-a, major third and fifth; c-g-c, fifth and octave; d-g-d, fourth and octave; d^b-f-b, major third and major sixth; a-f-a, minor sixth and octave; b-a^b-b, major sixth and octave; d-g-b, fourth and major sixth; and c-e-c, major third and octave. Similarly for the other *O*'s.)

In these experiments the stimuli were allowed to sound for one sec. *Vexirversuche* of two-note complexes were occasionally interspersed. The instructions were similar to the previous experiments, except that the phrases "two-note" and "three-note complexes" were substituted for "single notes" and "two-note complexes." It was not long before the judgments and the length of reaction times furnished *E* with sure indication that certain of the triads were submitting very imperfectly to analysis. Judgments of "two" for three-note complexes were very frequent; or the time of reaction was often so great that *E* lost count of the number of swings of the pendulum across the 2000 σ scale. *E* secured introspective descriptions of the impressions aroused by these more imperfectly analyzable triads. The qualitative data thus obtained put *E* in the possession of valuable descriptive material for experiments to be mentioned presently.

It now appeared desirable to adopt a direct method of observation.¹⁴ The method of paired comparisons provided a suitable form of procedure. Every one of the twelve intervals was paired with the eleven other intervals six times, making thus $(12 \times 11)/2$ comparisons $\times 6$ repetitions = 396 judgments in all. There were 11 comparisons $\times 6$ repetitions = 66 total possible preferences for any one interval. The intervals were arranged in haphazard order, with the precaution that no interval should be presented twice in succession. The components for the intervals were all included within the range of a major 9th, from b^b of the small octave (234.66 d.v.) to c² of the twice-accented octave (528 d.v.). With an eye to the time-error, the order of presentation of the intervals within a pair was reversed in alternate series. It was possible to secure about 100 judgments in each experimental session.

The following instructions, derived from the Stumpfian *Folgeerscheinung* of *Einheitlichkeit*, were read by *O* at the beginning of every session: "Following the 'ready' signal, you will be presented with a successive pair of tonal complexes. In each case you are to compare the two impressions with respect only to degrees of unitariness, regardless of other possible characteristics of the impressions. Report 'first' or 'second' according as the first or second impression is more unitary. If there is no difference between them, report 'same.'"

These instructions proved to be highly equivocal for all *O*'s, for they soon discovered that the meaning of unitariness might be carried by quite different sensory data present in the total tonal impression. The judgments were made only with extraordinary difficulty and reported with still greater reluctance, for *O* was peculiarly loth to trust his judgment when faced with several processes all of which were possessed of potential contexts for unitariness in nearly equal degrees of mediacy.

¹⁴ On direct *vs.* indirect methods in work on tonal fusions, see Kemp, *op. cit.*, 163-179.

The situation thus created is interesting in the light of recent attention to the "stimulus-error" in psychophysics.¹⁵ Ordinarily a careful control of attitude is necessary to secure univocal determination in psychological experiment. The experiments of George¹⁶ indicate the ease with which equivocal criteria may arise with inconstancy of attitude, and the recent work of Friedländer¹⁷ and Fernberger¹⁸ with lifted weights makes clear the effect of this inconstancy upon the objective results which psychometric functions represent. The manner in which the limens for dual impression upon the skin may vary under attitudinal shifts has become well established in cutaneous psychophysics.¹⁹ This development simply serves to give impetus to the current urge in experimental work for a sharper delineation of observational attitudes, to the end that a more univocal correlation may be arrived at between the terms in the total chain of experience. This chain, following Urban's²⁰ schema, may be represented by $\alpha, \beta, \gamma, \dots$ for physical conditions (stimulus-situation), a, b, c, \dots for physiological processes of nerve excitation, and A, B, C, \dots for contents of consciousness. Since similar terms in these three systems, as β, b, B , are not in experimental practice univocally correlated, it becomes necessary to discover what factors in the A, B, C, \dots system are correlated, e. g., with β in the stimulus-situation; and it may turn out that the conscious correlates of β are A, C, M , and P , depending on the nature of the *Aufgabe* which is operative in the stimulus-situation. If the *Aufgabe* is not set carefully by instructional determinants, O may judge now upon one, now upon another, of the A, C, M, P , factors, so that it becomes scientifically absurd to speak of a correlation. Hence "the total *Aufgabe* under which the subject judges must be made definite in instructions, and must be more fully determined by means of repeated characterizations by the subject of his attitude and procedure. This latter check is important since much of the subject's instruction is apt to be a self-instruction."²¹

In the series of experiments under consideration, it became apparent that the O 's were laboring under an equivocal instructional determinant. Let it be supposed, for instance, that the tonal intervals in the stimulus-situation had among other conscious correlates the factors B, D, L , and Q , all of which were potentially associated with the contexts B', D', L' , and Q' , carrying the meaning for unitariness.

¹⁵ See especially E. G. Boring, The control of attitude in psychophysical experiments, *Psychol. Rev.*, 1920, 27, 446ff., 449; The stimulus-error, *Amer. J. Psychol.*, 1921, 32, 449ff.

¹⁶ S. S. George, Attitude in relation to the psychophysical judgment, *Amer. J. Psychol.*, 1917, 28, 1ff.

¹⁷ H. Friedländer, Die Wahrnehmung der Schwere, *Zeits. f. Psychol.*, 1920, 83, 129ff.

¹⁸ S. W. Fernberger, An experimental study of the "stimulus-error," *J. Exp. Psychol.*, 1921, 3, 63ff.

¹⁹ E. B. Titchener, Ethnological tests of sensation and perception, *Proc. Amer. Philos. Soc.*, 1916, 55, 206-215; E. deLaski, Perceptive forms below the level of the two-point limen, *Amer. J. Psychol.*, 1916, 27, 569-571; C. L. Friedline, Discrimination of two cutaneous patterns below the two-point limen, *ibid.*, 1918, 29, 400-419; and especially Boring, The stimulus-error, *Amer. J. Psychol.*, 1921, 32, 449ff.

²⁰ F. M. Urban, Ueber einige Begriffe und Aufgaben der Psychophysik, *Arch. f. d. ges. Psychol.*, 1913, 30, 116-118.

²¹ Boring, *Psychol. Rev.*, 27, 449.

Under the *Einstellung* laid down by the instructional determinant for unitariness, *O* would have a wide and unchecked range for equivocal judgments which would issue in rank order of degrees of unitariness of which the scientific significance would be small.

CHART 1

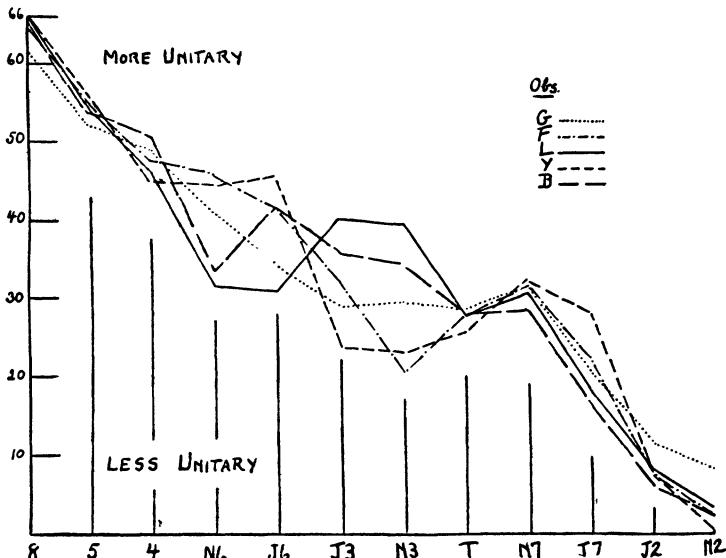


CHART 1. Rank-order of tonal intervals under instructions for 'unitariness' (see text). Method of paired comparisons. Ordinates represent number of discriminations for every interval for five *O*'s. Abbreviations: 8 = octave, 5 = fifth, 4 = fourth, N6 = minor sixth, J6 = major sixth, J3 = major third, N3 = minor third, T = tritone, N7 = minor seventh, J7 = major seventh, J2 = major second, N2 = minor second.

In Chart 1 are shown the curves derived from judgments of unitariness. In all the charts the intervals on the abscissa have been arranged in the same order for ease of intercomparison. The numbers on the ordinate represent the frequency of preferences. The curves of Chart 1 make clear the rather significant fact that *O*'s can take up a stimulus-attitude toward mental experience and come out with a surprising degree of uniformity. The net returns to psychology of such agreement of results are small, however, inasmuch as no light is thrown upon the mental processes involved in the judgments.

At the end of this series of experiments, the *O*'s were asked for introspective characterizations in which should be noted the criteria which had entered into or cut across the judgments of unitariness. These reports, together with the qualitative data secured from the earlier preliminaries, furnished the material out of which grew the experiments now to be considered.

PRINCIPAL SERIES

The method and procedure in the following series were the same as in the foregoing experiment. The only difference lay in the instructions given to *O*. From the introspective data at hand were selected those factors in the *A, B, C, . . .* system of tonal mental processes which approximated the phenomenological level of experience. It was hoped by means of instructions and self-checking on the part of *O* to limit the judgments to a single factor, and thus come out with rank orders of which the significance would be more certain. Certain of the factors employed as criteria of judgment were common to the introspective reports of all the *O*'s; others, especially those of a contextual nature, followed the idiosyncrasies of individual differences and could be used as instructional determinants only for particular *O*'s. Before beginning work on a new criterion, one observational session was devoted to practice judgments, in order that *O* might familiarize himself with the new factor and become sufficiently *eingestellt* to take up a similar attitude in subsequent sessions. Whenever, during the series, *O* noted a lapse in attitude or found it impossible to make a judgment in accordance with instructions, he was expected to report the fact to *E*. At the end of every series *O* was requested to give a descriptive characterization of his attitude and basis of judgment.

Auditory Processes

Smoothness-roughness.—The first criterion to be used had as its sensory basis the 'smoothness' and 'roughness' of the auditory impressions. This factor had been frequently reported in all the introspections, and was easily taken up and followed through by all the *O*'s. The instructions for this series read as follows:

"Following the 'ready' signal, you will be presented with a successive pair of tonal complexes. In each case you are to compare the two impressions with respect only to degrees of 'smoothness' and 'roughness,' regardless of other possible characteristics of the impressions. Report 'first' or 'second' according as the first or second impression is 'smoother' or less 'rough.' If there is no difference between them, report 'same.' Whenever you fail to live up to instructions or find it impossible to make a judgment on the basis of the above criterion, report 'failure.'"

The purpose of such an instruction was to get *O* univocally determined in the direction of auditory 'smoothness-roughness' and away from other possible factors in the tonal impression.

The descriptive characterizations point to 'roughness' as the positive category in this series, and to 'smoothness' as the absence of 'roughness.' 'Roughness' is a temporal-intensive pattern in which intensity varies in time, whereas complexes in which intensity seems relatively constant are 'smooth.' Comparison-judgments between complexes in which the variation of intensity is rapid and those in which intensity variations are slow (minor thirds and major seconds *vs.* minor seconds) embarrassed some of the *O*'s. This difficulty they usually resolved by judging as 'smoother' those complexes in which the intensity variations are more rapid.

CHART 2

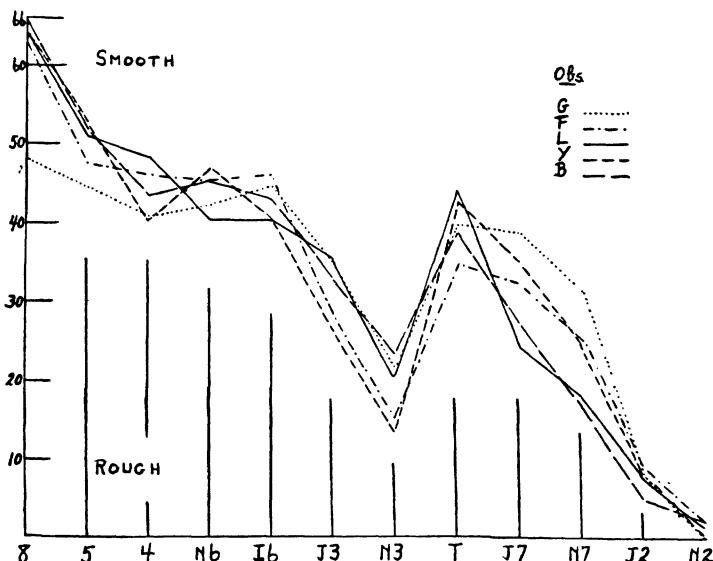


CHART 2. Rank-order of tonal intervals under instructions for 'smoothness-roughness' (see text). Curves for five *O*'s.

Chart 2 indicates the rather striking uniformity of rank orders obtained under this attitude. It will be noted that 'smoothness' and 'roughness' vary with the physical distance of the components of the interval: the octave, fifth, fourth, sixths, tritone, minor seventh, and major third all come higher

on the scale than the minor third and the seconds. The relatively low position of the major seventh must be due to the presence of overtones which cut across the factor of distance.

Simplicity and Complexity.—The next two criteria of judgment to be adopted took their root in the general phenomenon of analysability. The possibility of taking up two attitudes in this respect made it advisable to follow through separate series. The instructions in the first series, as, in point of fact, for all subsequent series, were worded like the instructions for 'smoothness-roughness,' except in those phrases intended to determine *O* in a new direction:

"Following the 'ready' signal, you will be presented with a successive pair of tonal complexes. In each case you are to compare the two impressions with respect only to degrees of 'simplicity.' By 'simplicity' is meant the degree of approximation to singleness of auditory core, *i. e.*, unanalysability of the impressions. Report 'first' or 'second' . . . " etc.

The instructions for the second series read:

" . . . In each case you are to compare the two impressions with respect only to degrees of 'complexity,' *i. e.*, you are to state in which of the two impressions the components separate most during presentation. . . ."²²

The introspective data for the 'simplicity' series indicate that the criterion here involves difficulty of analysis or independent variability of clearness of components in time, which occurs under a fairly active attitude (=attentional attempt at analysis). This is to say that those complexes in which it takes longer for the total impression to split up into its separate components, or in which one component dominates the other in clearness, are judged as more 'simple' inasmuch as they approximate more nearly to singleness of auditory core.

In the 'complexity' series, on the other hand, the judgments are made under a more passive attitude. *O* reported merely upon the relative "analysedness" of the impressions as given during presentation of the stimulus, and not upon 'analysability.'

²² During the practice period for this series it was discovered that the *O*'s were often uncertain in their judgments because of the change which the impressional contents for judging underwent during the formulation of the judgments in the course of the immediate memory after-images. Hence they were instructed to base their judgments upon the contents as they appeared *during presentation*. To facilitate this mode of judgment, the exposure time of each interval was reduced from 2. to 0.5 sec. (measured by a silent metronome).

In Chart 3 are shown the curves for the 'simplicity' series. The 'simplicity' curves for G and B turned out to be nearly identical with their 'complexity' curves, and have therefore been placed as G(s) and B(s) on Chart 4 ('complexity') instead of on Chart 3 (the other 'simplicity' curves). The three curves of Chart 3 follow fairly closely the Stumpfian order of degrees of fusion, except for the rather high positions of the tritone and minor seventh, a possible explanation of which will be mentioned presently. The 'complexity' curves deviate from the 'simplicity' curves in a uniform and significant manner. Those intervals of which the components lie far apart on the tonal scale (sixths and sevenths) occupy the lower positions on the chart, whereas those intervals of which the components are proximate (thirds and seconds) occupy uniformly higher positions. The high positions of the octave, fifth, and fourth, are undoubtedly referable to the factor of 'fusion'²³ which cuts across the factor of sense-distance. The opposed positions of the seconds on the two charts demand a word of explanation, an explanation forthcoming in the introspections, which show quite definitely that two different attitudes are operative in the case of the seconds: a 'meaning' attitude and a descriptive attitude. The O's whose curves for the 'simplicity' series are represented in Chart 3 judged certain of the intervals 'less simple' on the basis of contents which carried the meaning of non-simplicity rather than on the basis of relative degrees of simplicity of the auditory experience *per se*. The following quotations from their introspective characterizations illustrate the point:

Ob. F. "In some cases one of the complexes comes as very rough. It has the meaning of being readily analyzable at once. How this meaning is present structurally I cannot say, although the basis of it seems to be roughness. There is a verbal characterization of it as 'less simple,' but there does not seem to be any auditory attentional analysis."

Ob. L. "I tend naturally to judge as not simple a complex which produces roughness, or one where the 'noise' stands out prominently."

Ob. Y. "In such a case [comparison of a rough complex with a smooth one, the components of which stand out clearly] the rough one is usually cognized as a complex of two tones, more immediately than the other. Yet, since it was very difficult to split up the rough interval into two components actually, *i. e.*, psychologically, I judge it as simpler."

²³ The word "fusion," when used in connection with the curves under consideration, bears no theoretical implications: it is merely a convenient term to apply to those intervals whose components either will separate out only with difficulty (=unanalysability) or do not fall apart during presentation (=unanalysedness).

Y's report shows that he was aware of his two attitudes, but his curve points to only a partial approximation to the psychological descriptive attitude: more often he judged the rough intervals on the level of cognizance and meaning. In the complexity series, however, he was able to abide quite rigidly by the descriptive attitude, as his curve indicates. L, too, was able to keep to the descriptive attitude fairly consistently in the 'complexity' series, although not to the extent

CHART 3

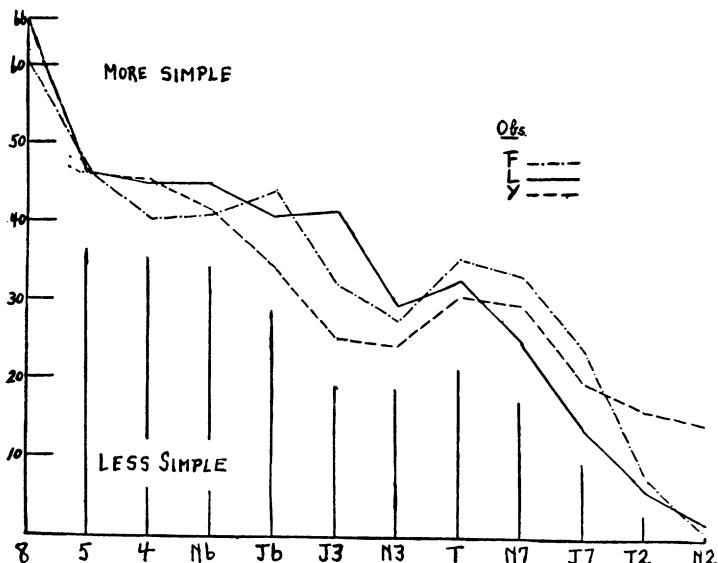


CHART 3. Rank-order of tonal intervals under instructions for 'simplicity' (see text). Curves for three O's. 'Simplicity' curves for two O's are shown in Chart 4.

of the other O's; at least the low position of her curve at the seconds would seem to warrant such a statement. It is matter for regret that circumstances made it impossible for F to complete the 'complexity' series.

Regarding the high positions of the tritone and minor seventh in the 'simplicity' series, adverted to above, it may be that this very factor of attitude is operative. In the 'smooth-rough' series the tritone and minor seventh occupy relatively high places, and since 'roughness' was part-mediator for the meaning of 'less simple,' it is reasonable to sup-

pose that 'smoothness' may have entered in at times to support the meaning of simplicity, and thus give to the tritone and minor seventh values higher than would otherwise have been the case. It is not clear, however, why for two of the *O*'s the 'simplicity' series gave curves like the 'complexity' curves. A valid explanation can be sought only in repeated experiments under more stringent control of instructional determinants.

CHART 4

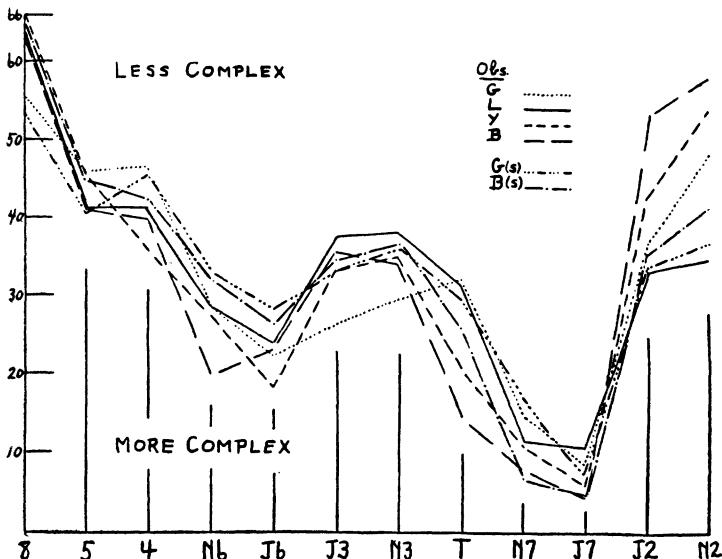


CHART 4. Rank-order of tonal intervals under instructions for 'complexity' (see text). The curves for *G*(*s*) and *B*(*s*) are 'simplicity' curves (see Chart 3). The four 'complexity' curves are inverted.

Pleasantness and Unpleasantness.—Although in the preliminary experiments, the *O*'s had stated that pleasantness and unpleasantness entered but seldom as disturbing criteria of judgment, it was deemed advisable to run through a series of *P* and *U* in order to discover just how judgments would come out under an affective determination. The instructions were similar to previous ones with the exception that *O* was requested to judge in terms of *P* and *U* only.

Under the conditions of the present experiment, *P* and *U*

turn out to be meanings for all *O*'s,²⁴ or at least experiences not *sui generis*. For *F* and *Y*, the introspective reports state the potency of 'smoothness' and 'roughness' as mediating factors in the affective judgment, a fact borne out by the resemblance of the curves of *F* and *Y* (Chart 5) to the 'smooth-rough' curves. The agreement of these two curves and the agreement of the other three curves, and the marked difference between the two types, are worthy of especial note.

CHART 5

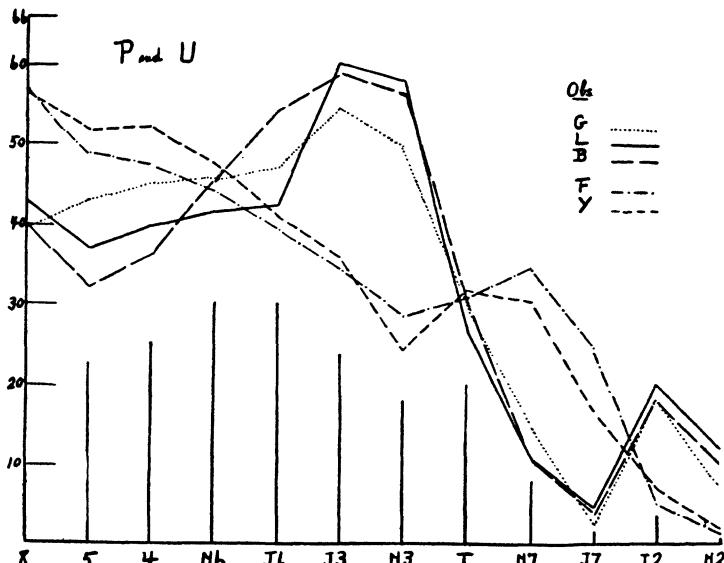


CHART 5. Rank-order of tonal intervals under instructions for *P* and *U*. Curves for five *O*'s.

For *G*, *L*, and *B*, whose curves represent the second type, the *P* and *U* judgments are explicitly reported as being on the level of meaning. Just what the sensory mediators for the judgments represented by these curves may be can not be satisfactorily gleaned from the introspective reports, although hints are not wanting to point to non-auditory concomitant processes of the auditory experience as playing a part. (See below: the "horrisonorous" curve for *G*, the "rotundity"

²⁴ For a recent exposition of the resemblance between affection and meaning, see M. Yokoyama, *The nature of the affective judgment in the method of paired comparisons*, *Amer. J. Psychol.*, 1921, 32, 357ff.

and "hard-soft" curves for L, and the "kinaesthesia" curve for B.) Perhaps the most interesting feature of these curves is their consistency with musical usage: the sixth and thirds are very pleasant; the minor seventh and seconds are unpleasant and the major seventh very unpleasant; the octave, fifth and fourth are rather "indifferent."

So far the judgments under varying attitudes have come from instructions the purport of which was to determine *O*

CHART 6

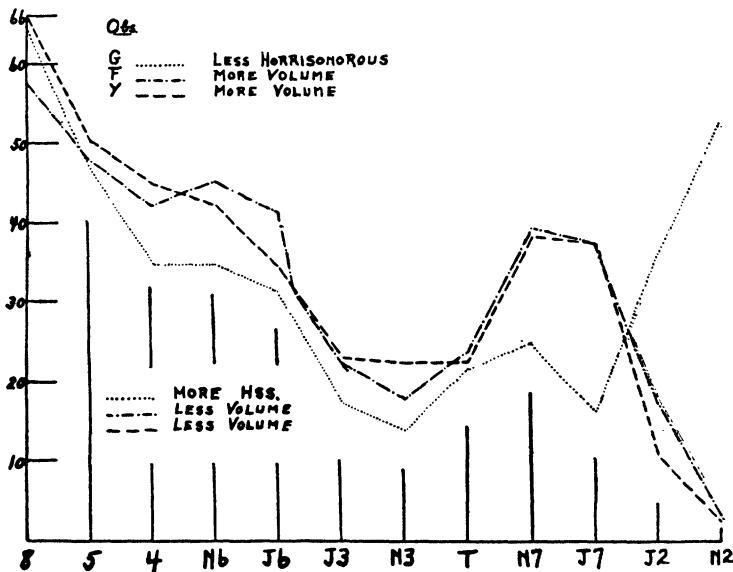


CHART 6. Rank-order of tonal intervals under criteria into which entered integrations of auditory and non-auditory processes (see text). Curves for three *O*'s. The curve for *G* is inverted.

in the direction of purely auditory aspects of the total contents set up by the stimulus-situation. In the qualitative analyses of the preliminary experiments, however, there were numerous references to non-auditory concomitant processes, or to integrations of auditory and non-auditory processes, which presented themselves as important parts of the whole impression or as strong candidates for judgment in the case of unitariness. For the sake of greater completeness, therefore, although an exhaustive study of all possible factors in the *A*, *B*, *C*,

. . . system was of course out of the question in the time at our disposal, it was decided to follow through certain of the more insistent contextual processes.

Integration of Auditory and Non-auditory Processes

The curves of Chart 6 represent rank orders from judgments based on an intimate integration of auditory and non-auditory processes. The criterion of this sort followed through by F was integration of the voluminous aspect of the auditory impression and a concomitant chest-kinaesthesia of varying degrees of expansiveness; a similar criterion by Y, an integration of the same voluminous factor and a concomitant visual process between the two extremes of which a gap of varying width could be observed. In addition to the close uniformity of the two curves there should be noted also the factor of distance of components on the tonal scale, which is again operative: the low position of the thirds and seconds in which the paired components are close together, and the high position of the sevenths and sixths in which the paired components are farther removed from each other. Otherwise the form of the curves is similar to that for the 'simplicity' series. The criterion adopted by G in this group was an integration of auditory and kinaesthetic processes to which, for the sake of convenient reference, he originally gave the term "horrisonorous." By this term he meant the vibrant, rather unpleasant, factor in the auditory experience (*horridus*) together with the auditory fulness and richness of the impression. Although on closer observation G became convinced that the pattern of "horrisonorousness" consisted of an intimate integration of ear-kinaesthesia and auditory quality which could only be separated under careful attentive analysis, he still retained the term. The form of G's curve is similar to those for F and Y, and what has been said concerning these latter is equally true of the former. The one exception, in the case of the seconds, is explained in G's introspections by the fact that with the coming in of marked roughness the "horrisonorous" factor is 'swamped.' (The curve has been inverted on the chart.) Were it not for this rapid rise of the curve at the seconds, the resemblance to the other two curves would be still greater, inasmuch as a lowering of the curve at one point would result in an elevation at another, the essential event in this case for bringing about a greater agreement.

Concomitant Non-auditory Processes

Chart 7 gives the curves for judgments based on purely non-auditory concomitant processes. L, who is of a marked visual type, was able to make judgments on various aspects of what she called a 'pseudo-visual' image, *i. e.*, kinaesthesia of eye-movement which served as an effective surrogate for the actual visual experience. By 'rotundity' she meant the fulness and size of the visual image; by 'hard-soft,' the texture

CHART 7

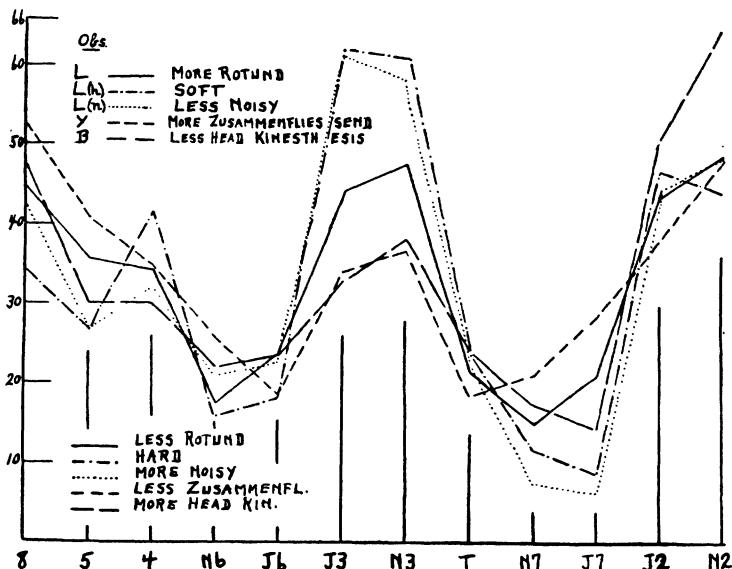


CHART 7. Rank-order of tonal intervals under criteria into which entered concomitant visual and kinaesthetic processes (see text). Curves for three O's. The curves for L(h), L(n), and B are inverted.

of the image; and by 'noise component,' the jagged or even contour of the image. Y followed through a criterion which he called visual *Zusammenfliessen*, by which he meant the pulling together or apart of concomitant visual images in the field of vision. By 'head-kinaesthesia' B referred to varying degrees of extension of concomitant kinaesthesia across the posterior portion of the head. It can be seen at a glance that there is less agreement among the curves of Chart 7; nevertheless a marked directional uniformity is apparent at the

TABLE I
 FREQUENCY OF JUDGMENTS UPON TONAL INTERVALS UNDER VARIOUS CRITERIA. METHOD OF PAIRED COMPARISONS.
 COLUMN AT LEFT REFERS TO PARTICULAR CRITERION OF JUDGMENT. SEE CHARTS AND TEXT. ABBREVIATIONS: 8 = OCTAVE, 5 = FIFTH, 4 = FOURTH, 3 = THIRD, 2 = SECOND, 1 = FIRST.
 G = MAJOR, J = MINOR, N = TRITONE

Criterion	Obs.	8	5	4	N6	J6	J3	N3	T	N7	J7	J2	N2
Chart 1 Unitariness	G	61 1/2	52	49	41	34	29	29 1/2	28 1/2	31 1/2	20 1/2	11 1/2	8
	F	64 1/2	55	47 1/2	45 1/2	41 1/2	32	20 1/2	27 1/2	31 1/2	22	7 1/2	1
	L	66	54 1/2	46	31 1/2	31	40	39 1/2	27 1/2	30 1/2	18 1/2	8	3
	Y	66	55 1/2	45	44 1/2	45 1/2	23	23	25 1/2	32	28	7 1/2	0
Chart 2 Smooth-Rough	B	65 1/2	54	50 1/2	33 1/2	41 1/2	35 1/2	34 1/2	28	28 1/2	16 1/2	6	2
	G	48	44 1/2	41	42 1/2	44 1/2	35	21 1/2	40	39	31 1/2	8 1/2	0
	F	63	47 1/2	46	45 1/2	46	28 1/2	15 1/2	35	32 1/2	25 1/2	9	2
	L	64	51	48 1/2	40 1/2	40 1/2	35	21	44 1/2	24 1/2	18	7 1/2	1
Chart 3 Simplicity	Y	64	52 1/2	40 1/2	47	40 1/2	26 1/2	13 1/2	43	35	25	8 1/2	0
	B	65 1/2	51 1/2	43 1/2	45 1/2	43	33	23 1/2	39	27	17 1/2	5	2
	F	60 1/2	46 1/2	40 1/2	41	44	32 1/2	27 1/2	35 1/2	33 1/2	24 1/2	8 1/2	1 1/2
	L	66	46 1/2	45	45 1/2	41 1/2	41 1/2	29 1/2	33	25	14	7	2 1/2
Chart 4 Complexity	Y	66	46	45 1/2	41 1/2	34 1/2	25 1/2	24 1/2	31	30	20	16 1/2	15
	G (s)	53 1/2	40 1/2	45 1/2	33 1/2	28 1/2	33 1/2	36	29 1/2	17	7 1/2	34	37
	B (s)	65	45	42	32	26 1/2	34 1/2	36 1/2	25 1/2	7	5	35 1/2	41 1/2
	B	55 1/2	46	46 1/2	28 1/2	22 1/2	26 1/2	29 1/2	32	15	9	37	48
Chart 4 Complexity	G	64	41	41	28 1/2	24	37 1/2	38	31 1/2	11 1/2	11	33 1/2	34 1/2
	Y	66	45 1/2	35 1/2	27 1/2	18 1/2	33 1/2	35 1/2	20 1/2	11	6	4 1/2	54
	B	63 1/2	41	40	20	23	35 1/2	34 1/2	14 1/2	8	4 1/2	53 1/2	58

position of certain of the intervals. As in Chart 6 the 'distance' factor is operative here, although in the opposite direction: the thirds and seconds (intervals whose components are proximate) rank relatively high, and the sevenths and sixths (distant components) low. Unusually low positions of the octave, fifth, and fourth are undoubtedly due to the violence with which the 'distance' factor intrudes upon the 'fusion' factor: note the extremes attained by the thirds and sevenths.

CONCLUSIONS

The numerical data from which the charts have been drawn are summarized in Table 1. The fractional numbers there derive from the usual procedure in the method of paired comparisons of giving equal value (*i. e.*, $\frac{1}{2}$) to each member of a pair in an equality judgment.

The results indicate clearly the complexity of the tonal impression that is dependent upon the presentation of bitonal stimuli. Various factors which make for this complexity may be isolated by means of carefully controlled instructional determinants and examined apart. Such isolation and examination as the present study has undertaken bring to view certain of the phenomenological characteristics which constitute the foundation of bitonal impressions.

Smoothness-roughness.—The continuum to which the expression 'smoothness-roughness' applies is best described in terms of 'roughness.' By 'roughness' the *O*'s meant a temporal-intensive pattern in which various rates of intensive oscillations of the auditory experience are observable. 'Roughness' is inversely proportional to the rapidity of intensive oscillations. 'Smoothness' is the absence, or relative absence, of intensive oscillations. Absolute 'smoothness' is a continuation in time of the auditory experience without observable variations in intensity.

Simplicity.—By 'simplicity' the *O*'s intended the phenomenon of unanalysability. The introspective reports show that by unanalysability they meant the covariation in sensory clearness of the auditory components under an active attitude (==attentional analysis) by virtue of which isolation of one component becomes difficult, that is to say, occurs only incompletely or only after a considerable interval, or else, on occurring, persists only for a short time. The tonal complexes are judged increasingly less 'simple' as the variation in clearness of the components becomes more independent.

Complexity.—For judgments of 'complexity' the *O*'s assumed a more passive attitude, *i. e.*, an attitude for judging

upon the 'complexity' of the interval as it appeared *during presentation*, rather than an active attempt at attentional analysis. From the introspective characterizations it becomes apparent that the *O*'s understood by 'complexity' the degree of disparity (nearness or remoteness on a scale of 'sense-distance') of the auditory pitch qualities as they appear in the tonal impression. Those intervals in which the components are readily perceived as disparate with respect to pitch quality are judged as 'complex,' whereas those intervals in which the pitch qualities are less readily perceived as separated or dual are judged as less 'complex.'

From a consideration of Chart 4 it becomes apparent that 'complexity' varies with physical distance: those complexes in which the components lie further apart on the tonal scale are judged more 'complex' than those complexes in which the components are proximate. Exceptions occur, however, in the case of the fourth, fifth, and octave. It would seem that the qualitative disparity of these intervals is obscured by a greater covariation in clearness of the components, the factor which makes for 'simplicity.' That is to say, processes which ordinarily lead to the judgment 'complex,' are cut across in the case of the octave, fifth, and fourth by more insistent processes leading to the judgment less 'complex' = more 'simple.' It should be noted that in the characterizations of 'simplicity' all the *O*'s except one had occasion to speak of those intervals in which covariation in clearness made analysis difficult as "stuck together," "glued together," "well knit," "well fused," "hanging together," *etc.* Such characterizations of the impressions, together with the fact that covariation in clearness cuts across and obscures qualitative disparity, make plausible the statement that covariation in clearness is related to a true perceptual 'fusion' of tones, *i. e.*, fusion is an integration of attributes of clearness rather than a qualitative integration.

Pleasantness and Unpleasantness.—None of the *O*'s based their affective judgments upon *P* and *U* *per se*. In all cases the judgments were of the nature of attitudinal or 'meaning' responses. For two *O*'s *P* and *U* turn out to have their sensory bases in 'smoothness' and 'roughness.' For convenience of reference the affective preferences of these two *O*'s may be designated as judgments of 'smooth' *P* and *U*. The other three *O*'s, whose affective preferences accord more with musical usage, were unable to give any thoroughgoing characterization of the sensory mediators for *P* and *U*. In lieu of a better term their affective judgments may be referred to as 'musical' *P* and *U*.

Volume.—Two *O*'s found it possible to characterize the intervals in terms of 'voluminousness' or 'fullness.' It is evident from their descriptive reports that 'volume' for them is not a purely auditory affair, but an integration of auditory process with certain contexts which attach to the intervals. For one *O* 'volume' is an integration of auditory process and chest-kinaesthesia; for the other, an integration of auditory and visual processes.

Horrisonorousness.—By this term one *O* meant an intimate integration of auditory quality and ear-kinaesthesia into a closely knit pattern of vibrant qualitative roughness. Originally, in the preliminary series, this *O* noted that 'horrisonorousness' was frequently affectively toned. The agreement of this *O*'s affective preferences with certain of his judgments on 'horrisonorousness' makes it possible that the latter and the sensory basis of 'musical' *P* and *U* have something in common.

Visual and Kinaesthetic Processes.—Three *O*'s followed through series in which judgments were made upon concomitant non-auditory processes alone. Terms such as 'rotund,' 'soft,' and 'noisy' refer to the size, smooth contour, and jagged texture of concomitant visual processes; 'zusammenfliessend' to the pulling together or apart of visual imagery; and 'head-kinaesthesia' to the spread of kinaesthetic process in the posterior portion of the head. (See Chart 7.)

It is now possible, with the aid of the foregoing terms, which stand for definite sensory experiences ('musical' *P* and *U* excepted), to characterize every interval separately with respect to various factors in the total impression which contribute to its constitution.

Octave.—The octave occupies an unique position among the tonal intervals in that it lies at one extreme of three of the attributive continua within which all intervals vary. It is the 'smoothest,' 'simplest,' and least 'complex' interval, in the sense of the discussion of the preceding paragraphs. With respect to 'smooth' affective judgments the octave is also the most pleasant interval. *O*'s whose affective preferences are of the 'musical' kind, however, find the octave about as pleasant as the fourth and fifth and less pleasant than the sixths and thirds.

By some *O*'s the octave was also characterized as giving a more 'voluminous' impression than the other intervals.

Fifth.—This interval resembles the octave in that it is marked by an almost complete absence of 'roughness.' One *O*, in fact, judged the fifth as practically equal to the octave

in 'smoothness.' The components of the fifth admit of more independent variation in clearness than do the components of the octave, that is to say, the fifth is slightly less 'simple.' This factor of 'simplicity' tends to predominate over the wide 'sense-distance' included in the fifth, so that the interval appears as less 'complex' than any of the other intervals except the octave. Under a 'musical' affective determination the fifth is slightly less pleasant than the octave except for one *O* who finds it somewhat more pleasant than the octave. The fifth is also less pleasant than the octave for those *O*'s whose affective judgments are mediated by 'smoothness.'

The contextual aspect of 'volume' when reported was more prominent in the fifth than in any other interval except the octave.

Fourth.—With respect to 'smoothness' the fourth is on an equal plane with the sixths, which are a little less 'smooth' than the fifth. In this interval the 'simplicity' factor again appears to obscure the 'complexity' aspect, so that only the fifth and octave are judged less 'complex' than the fourth. The fourth, fifth, and minor sixth all appear about equally 'simple.' 'Musical' affective judgments place the fourth before the fifth and the octave in *P*; 'smooth' affective preferences place the octave and fifth before the fourth in *P*.

For *G*, who judged upon a qualitative pattern of integrated auditory process and ear-kinaesthesia, the fourth assumed a trace of 'horrisonorousness.' The 'voluminous' characteristic, when it was observed, entered into the fourth to the same extent as in the sixths, which are exceeded in 'volume' only by the fifth and octave.

Minor Sixth.—The limits which various characteristics may reach under attitudinal changes vary more between intermediacy and extremes in the minor sixth than in the three preceding intervals. The fourth and both the sixths are very 'smooth' intervals and are exceeded only by the fifth and octave in this respect. The remoteness of the pitch qualities in the minor sixth lends to the interval an aspect of 'complexity' which is more marked only in the major sixth and the sevenths. On the other hand, under an active attitude of attentional analysis, the relative lack of independent variability in clearness of the components leads to the judgment 'simple' in the case of three *O*'s, that is to say, perceptual 'fusion' is more insistent than qualitative disparity. 'Musically' the minor sixth is more pleasant than any of the

preceding intervals. When mediated by 'smoothness,' however, it is less pleasant than the preceding intervals.

For two *O*'s, only the octave and fifth exceeded the minor sixth with respect to 'voluminousness.' *G* found 'horrisonorousness' present in this interval to the same extent as in the fourth. For certain *O*'s contextual and kinaesthetic processes became palpable in the minor sixth to an extent which would tend, under an equivocal determination, to obscure the purely auditory aspects of the impression.

Major Sixth.—The qualitative disparity of the components of the major sixth is even more marked than in the minor sixth, giving thus to the interval an aspect of 'complexity' exceeded only by the sevenths. Under the determination for 'simplicity,' however, three *O*'s find but little difference in 'simplicity' between the major sixth and the minor sixth and fourth. The major sixth is on equal terms with the minor sixth and fourth with respect to 'smoothness.' Only the thirds are pleasanter than the major sixth under a 'musical' affective determination. The other affective judgments place the major sixth just below the preceding intervals in *P*.

'Volume' was somewhat less and 'horrisonorousness' slightly more apparent in the major sixth than in the preceding intervals, for the *O*'s who found these contexts. As in the minor sixth, kinaesthetic and visual processes may have come in to obscure the auditory processes in the major sixth.

Major Third.—The relative position with respect to the other intervals of the major third, and also the minor third, varies considerably under attitudinal changes. Between the major third and the intervals already mentioned there is a marked difference in 'smoothness.' Only the minor third and the seconds are 'rougher' than the major third. Only the octave, fifth, fourth, and seconds are less 'complex,' and the octave, fifth, fourth, and sixth more 'simple,' than the major third. The relative 'simplicity' and 'non-complexity' of this interval are presumably not due so much to the covariation of clearness and the parity of pitch qualities of the components as to the obliteration of these processes by the rapid intensive variations of the temporal 'roughness' pattern. The major third is the most pleasant of all the intervals for those *O*'s whose affective judgments have a 'musical' mediation, whereas it is "indifferently" toned for the two other *O*'s.

The auditory-kinaesthetic context of 'horrisonorousness' was very prominent in this interval for *G*. For *F* and *Y* the 'voluminous' context of the major third was almost lacking. The auditory factors of the major third may also have been

considerably obscured by visual and kinaesthetic concomitant processes.

Minor Third.—With the exception of the preceding interval, the minor third is the most pleasant interval for those *O*'s whose affective judgments are of the 'musical' sort. The interval is rather unpleasant for those *O*'s whose affective preferences are mediated by 'smoothness.' One of the most striking characteristics of this interval is the prominence of the factor of 'roughness.' Only the seconds, and for two *O*'s the major seventh, are 'rougher' than the minor third. As with the major third, the temporal-intensive pattern of 'roughness' seems to blot out the separate auditory qualities with the result that the minor third is judged as relatively 'non-complex.' Three *O*'s find the minor third, however, less 'simple' than any of the preceding intervals because of a shift to a 'meaning' attitude in the presence of the 'rough' intervals; that is to say, intervals in which oscillations of intensity are very prominent are cognized as 'non-simple' by virtue of this very factor of 'roughness.'

'Horrisonorousness' was more prominent in the minor third than in any other interval for *G*. Concomitant non-auditory processes manifested themselves to a great extent in the minor third.

Tritone.—In none of the aspects which enter into tonal impressions does the tritone seem to occupy an extreme position with respect to the other intervals. Perhaps the most striking characteristic of the interval is its 'smoothness.' Only the group of intervals comprising the octave, fifth, fourth, and sixths, is smoother than the tritone. The qualitative disparity of its components is sufficiently marked to cause the interval to be judged as more 'complex' than the octave, fifth, fourth, thirds, and seconds, though not so 'complex' as the sixths and sevenths. For three of the *O*'s the tritone appears somewhat more 'simple' than the thirds. For all the *O*'s the tritone is "indifferently" affective.

G found 'horrisonorousness' rather well marked in the tritone, although not to so great an extent as in the thirds.

Minor Seventh.—The 'roughness' of the minor seventh is not very obvious, although, of course, the interval is not so 'smooth' as the tritone and the group of intervals already mentioned. It is about equal in 'roughness' to the major third. The qualitative disparity in pitch of the components of the minor seventh lends to the interval an aspect of 'complexity' only exceeded by the major seventh. Three *O*'s under a determination for analysability, however, find the minor

seventh rather 'simple,' *i. e.*, the independent variability in clearness of its components is not very marked. The interval is unpleasant for *O*'s whose affective judgments are mediated by 'smoothness' as well as for those whose judgments are 'musically' mediated, although less pleasant for the latter than the former.

O's, who judged on the basis of 'volume,' found the minor seventh very 'voluminous.' Other contextual processes were also apparent to a noticeable extent for some *O*'s.

Major Seventh.—With the exception of the seconds, and for three *O*'s the minor third, the major seventh is the 'roughest' interval. It is also the most 'complex' interval. Only the seconds, when cognized as 'non-simple' under a 'meaning' attitude, are judged less 'simple' than the major seventh. The interval is very unpleasant for all *O*'s. For the 'musical' type it is the most unpleasant, while for the 'smooth' type the seconds are somewhat more unpleasant. It can be seen that the extreme position which the major seventh occupies within certain continua tends to give it a unique status antipodal to the octave.

Only the thirds exhibited greater 'horrisonorousness' than the major seventh. For some *O*'s visual and kinaesthetic processes and the contextual 'voluminous' aspect entered very prominently into this interval.

Major Second.—Unquestionably the most striking feature of the major second lies in the violent intensive oscillations constituting the 'roughness' pattern. Only the minor second possesses this characteristic in a more pronounced degree. For all *O*'s the major second is very unpleasant. Under a 'meaning' attitude the seconds are cognized as the least 'simple' intervals; but under a strictly descriptive attitude they scarcely submit to psychological separation at all, *i. e.*, the auditory qualities can not be singled out in the face of the violent intensive variations which dominate the seconds to so great an extent.

The contextual factor of 'volume' dropped out in the seconds, as did also 'horrisonorousness.' The interval was rich, however, in kinaesthetic and visual processes.

Minor Second.—This interval is the 'roughest' of all. Under an affective determination of the 'smooth' type it is the most unpleasant interval. With respect to other aspects the minor second is similar to the major second: under a 'meaning' attitude an *O* knows that a violently 'rough' interval must be 'non-simple'; but under a descriptive attitude he

judges it as 'non-complex,' since the component qualities can not be separated out.

From the charts and the immediately preceding characterizations of the intervals it can be seen that the rank-order of certain bitonal complexes is more affected by change of attitude than is the rank-order of others. The thirds and sixths, *e. g.*, undergo greater alteration in position under varying instructional determinants than do the octave, fifth, and fourth. The seconds shift position very decidedly in the presence of a descriptive attitude as against a 'meaning' attitude; but since these differences of attitude are of a different order from those brought about by the more readily effective instructional determinants, the variation of the seconds may be left out of account in the present consideration. In the literature upon tonal fusions there is considerable agreement regarding the ranks of the octave, fifth, fourth, and seconds;²⁵ but the sixths, thirds, and sometimes the minor seventh, are variously placed by different experiments. In the present experiment the results of the 'unitariness' series (Chart 1) show a like agreement among *O*'s of the octave, fifth, fourth, tritone, sevenths, and seconds, and a considerable divergence for the thirds and sixths. The preceding discussion has shown that the sixths and thirds vary in rank more than the other intervals under change of instructional determinant. The difference becomes apparent if the averages of all the intervals of all the series, except the 'unitariness' series, are taken and their *M. V.*'s computed, and the intervals arranged in order in terms of decreasing size of *M. V.* This order is as follows: minor third, major sixth, minor sixth, major third, minor seventh, major seventh, octave, fifth, tritone, fourth, and seconds. It seems to indicate that the possibility of equivocal determination of judgment is greater for the sixths and thirds, and occasionally for the sevenths, than for the other intervals. This fact may explain the lack of agreement in the literature concerning the rank-order of these particular intervals, since the instructional limitation of an *O* to a particular sensory criterion is extremely difficult at best, and, in the absence of a previous knowledge of the phenomenological criteria available in tonal intervals, almost impossible.

²⁵ See *e.g.*, R. Schulze, Ueber Klanganalyse, *Philos. Stud.*, 1898, 14, 483; Stumpf, *Tonpsychologie*, 1890, ii, 135; A. Meinong and St. Wita-sek, Zur experimentellen Bestimmung der Tonverschmelzungsgrade, *Zeits. f. Psychol.*, 1897, 15, 191, 193; A. Faist, *ibid.*, 109-113; Kemp, *op. cit.*, 186-190; Pear, *op. cit.*, 66.